Association for Information Systems
AIS Electronic Library (AISeL)

AMCIS 1999 Proceedings

Americas Conference on Information Systems (AMCIS)

December 1999

Decision Support for Management Control of Complex, Mission-Critical Processes

William Spangler
West Virginia University

James Peters
Carnegie Mellon University

Decision Support for Management Control of Complex, Mission-Critical Processes

William E. Spangler
College of Business and Economics
West Virginia University
wspangle@wvu.edu

James M. Peters
Heinz School of Public Policy and Management
Carnegie Mellon University
jpeters@cmu.edu

Abstract

This paper describes the issues underlying the development of intelligent decision support in complex control environments. An effective DSS requires a rich understanding of complex processes, the goals the processes are to accomplish, the current environment in which the processes are operating, and the goals the human agent is attempting to accomplish. These requirements in turn form the basis for a theory of human interventions in these environments.

Introduction

Research on disastrous failures of complex, mission-critical processes (CCP) that function in dynamic, uncertain environments has created valuable guidance in developing management control systems for these types of processes (Reason, 1990). Management control theory provides conflicting guidance to management on how to structure a management control system for CCPs.

On the one hand, contingency theory of management control design argues that management control in dynamic and uncertain environments should focus on results and not actions, and allow the agent more latitude to adapt to changing conditions (Merchant, 1998; Greenstein, 1993). The reason for allowing the agent more latitude is that the uncertainty of the environment precludes management from specifying, ex ante, the best actions to take in any situation. Giving the agent a result to achieve and delegating the action choice decision to him/her allows the action choice to be informed by an analysis of the environment at the time a decision is needed and, therefore, creating a better action choice.

On the other hand, the CCP's complexity typically precludes the agent from having the necessary expertise to make appropriate action choices in all situations. In situations where the agent lacks the necessary expertise, contingency theory would argue for more action-based controls and against giving the agent more latitude to make action choices (Merchant, 1998). The critical nature of the CCP also gives management increased incentive to restrict the agent's actions, particularly where the agent lacks necessary expertise.

In developing control systems for a CCP, management would prefer to provide expertise to the agent and have the application of that expertise be informed by knowledge of the state of the process and its environment at the point the decision must be made. Having a panel of experts available at all times, however, is usually infeasible. One solution to this dilemma is to provide the agent with detailed procedures to follow when the CCP goes out of control (i.e., is in a state that violates management's goals for the CCP) or to provide the agent with detailed operations manuals for the CCP. Depending on required procedures runs the risk that they will be incomplete or inaccurate. Depending on detailed manuals is problematic because of the complexity of the system and, consequently, the sheer size of the manuals and volume of information the agent would have to process in a short period of time. A better solution is to use a decision support system (DSS) that can act as a surrogate for the panel of experts. For such a DSS to be effective, it would need to have a rich understanding of the process, the goals the process is to accomplish, the current environment in which the process is operating, and the goals the agent is attempting to accomplish. As a first step, we develop a theory that predicts and explains the action choices that agents make while controlling CCPs, and impound that theory in a computer model.

Characteristics of CCPs

Detailed procedures are appropriate when designers know, ex ante, what the appropriate action should be in any situation (Merchant, 1998, p. 27). Expert engineers generally design CCPs and they are normally thoroughly tested before they are implemented. Therefore, the causal relationships between process components and the behavior of the process are well understood. Because of the complexity of the environment, however, the agent, not the designers, will have more complete information about the decision context (Greenstein, 1993). In addition, not all appropriate control actions are determinable ex ante. Therefore, control actions can not be completely automated and human agents are needed to make control action decisions in real time. The combined use of automated controls, detailed procedures, and human agents creates a distributed decision-making environment. Control actions may be taken jointly by automatic control mechanisms embedded in the process, by a human agent assigned to controlling the process, or by both, potentially independently.

These distributed decision processes present a dilemma for management. At some point, conditions will dictate that the agent should deviate from the written procedures because either the conditions that exist were not anticipated by the procedures or the procedures are based on an invalid, and often implicit, assumption about some interaction either within the process or between the process and its environment. Since the agent will most likely have to defend any deviations from prescribed procedures to management, there may be a tendency for the agent to inappropriately conform to the procedure and, in doing so, cause the process to fail (Greenstein, 1993). Because the appropriateness of controls is context-dependent, the issue becomes whether or not the agent should override the pre-specified controls because doing so would be in the best interest of both the agent and management.

Deciding When to Divert from Procedures

The most problematic of the issues surrounding appropriateness is determining if the procedure is flawed because it is incomplete or based on erroneous assumptions. Such a determination would require that the DSS essentially develop a new control action in real time based on its understanding of the process and the state of the world at the time the control action decision must be made. Because of the complexity of the CCP, such a determination would probably be developed using a simulation procedure that allows the DSS to anticipate the reaction of the process to various control actions under various conditions. Because of the critical nature of the process, the DSS would also need to aid the agent in developing a rationale for deviating from prescribed procedures since failure to develop such a rationale might cause the agent to execute the procedure even though doing so would lead to suboptimal results.

Procedures also play a large role in the explanation and prediction of operator action. Because procedures are commonly employed in complex task environments as an instrument for standardization and control, for risk reduction, and for cost containment, understanding how and why people make decisions under these types of constraints becomes an important constituent of the situation assessment underlying a DSS model in these types of environments. Agents' decisions, in turn, often entail a consideration of procedural directives in the context of a situation that, at times, encourages a deviation from those directives. Agents are expected to follow procedures but at the same time are expected, on their own initiative, to notice and compensate for deficiencies in the procedures. Because the criteria for appropriate deviations are poorly- defined and documented, and because there is a strong bias toward executing procedures as written when controlling CCPs, agents are sometimes faced with the quandary of deciding what to do when they believe a procedure step is inappropriate. Because an agent is subject to disciplinary action even when a procedural deviation is the proper action to take in a particular situation, the agent is similarly biased to follow the literal directives of a procedure. An understanding of the circumstances under which a deviation is acceptable, along with the rationale or argument that supports the deviation, would help to establish a more situation-dependent set of criteria -- perhaps guided by the type of intelligent DSS described above -- for meting out rewards and punishments for procedural deviations.

Requirements for Decision Support of CCPs

An accurate and complete situation assessment, which necessarily includes the process events resulting from goal-based human planning, is critical to the structural and functional requirements of an intelligent DSS, and as such comprises the primary objective of this research. The DSS should be able to engage in a real-time, human-computer collaborative dialogue, and to anticipate and react to potential human interventions. Ideally, the DSS should understand the rationale underlying actual or proposed actions, and suggest actions or counter-actions based on that understanding.

The key goal of a DSS in the control environment described above is to be a surrogate for the CCP designer's expertise that is available to the agent at the point where (s)he needs to make an action choice. To be an effective surrogate, the DSS would need to know:

1. management's goals for the process;
2. the procedure's goals and their rationale;
3. the details of the process' causal relationships and how it was designed to interact with its environment, including the details of any automated control mechanisms; and
4. the state of the process and its environment at the point any control action needs to be taken.

The DSS needs this rich information set to:

1. establish the level of goal congruence between the procedures and management;
2. determine if the conditions required by the procedure were met and an action is specified by the procedure;
3. determine if the procedure had failed to anticipate the current conditions or was based on erroneous assumptions about the process; and
4. develop a rationale the agent can use to justify deviating from the procedures if such deviation is deemed necessary.

Constituents of the theory

A theory of procedure deviation underlying the computational model is dependent on four variables describing the interaction of the system state and the applicable control procedures. They are:

- *Availability of Procedure Pathways*: A procedure pathway is one of what might be several alternative series of steps through a procedure. The absence of a procedural pathway that achieves management's goals can provide a rationale for the agent to deviate from the procedure.
- *Procedural Conditions Met:* Each step or directive in a pathway has certain explicit conditions for its execution -- conditions that the original procedure designers felt were required in the circumstances under which the procedure would be executed. If those conditions do not comply with the current state of the world, execution of the step, and traversal of the pathway, will result in a violation of procedure constraints. The agent will not execute a procedure whose conditions are not satisfied unless there is evidence that the procedural goals are congruent with management's goals even with the condition violated.
- *Completeness and Validity of Procedural Assumptions:* In defining a procedural step's conditions, the process designers made assumptions about what conditions would exist and at the time agent would consider the step for execution. They also made assumptions about what goals the procedure would need to accomplish to attain management's goals for the process. Because a pre-formulated procedure cannot anticipate every possible situation that might arise during procedure execution, a procedure might direct or prohibit execution of a step based on possibly incorrect assumptions concerning the state of the world or the procedural goals that need to be achieved. If so, an actor who decides to violate the procedure might construct a rationale in part by citing the validity, or lack thereof, of inferred assumptions.
- *Importance or Dominance of Conditions and Assumptions:* A step constraint (condition or assumption) is considered *dominant* when the cost of violating it outweighs the benefits (in terms of goal achievement). Thus, for example, a dominant, satisfied condition motivates an agent to execute the step. Conversely, a dominant, unsatisfied condition motivates the agent to avoid execution of the step – in effect to act independently of the procedure in pursuit of goal achievement.

These variables form the basis of a more extensive theory of procedure deviation that predicts and explains human interventions in complex control environments. The theory was constructed from analysis of empirical data gathered in a human-mediated, process control environment (i.e., Nuclear Power Plant (NPP) operations) that included the relevant procedures and the reasoning of operators, as evidenced by their utterances and actions, during simulated plant emergencies. The goal of the theory is to predict, and then explain, the behavior of the complex system based on a description of the CCP. The theory was operationalized in a computational model to facilitate applying it to cases and determining what its predictions would be. A detailed description of the model can be found in Spangler (1995).

Bibliography

Greenstein, S. (1993), "Procedural Rules and Procurement Regulations: Complexity Creates Tradeoffs," *The Journal of Law, Economics, and Organizations* (9:1), pp. 159-180.

Merchant, K.A. (1998), *Modern Management Control Systems: Text and Cases* (Upper Saddle River, NJ: Prentice Hall).

Reason, J. (1990), *Human Error* (New York: Cambridge University Press).

Spangler, W.E. (1995). *A Computer Model of Reactive Planning and Implementation Strategy in Program-constrained Decision-making*. Unpublished Ph.D. Dissertation. University of Pittsburgh, Katz Graduate School of Business.